Integration in Water Resource Management: Challenges, Concepts and Opportunities

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Executive Summary

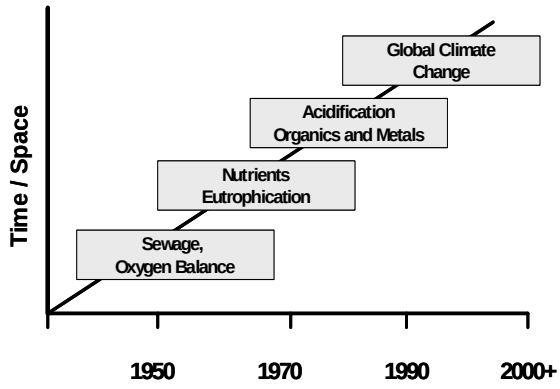
Recognition of similar objectives for meeting the challenges of water resource management led to the conduct of a forum involving the US Army Corps of Engineers (USACE) and those participating in research in support of the European Union's (EU) Water Framework Directive (WFD; European Commission 2002). The forum provided a unique opportunity to explore common issues and challenges, and identify potential collaborative efforts for overcoming such challenges. Central themes discussed were (1) system-wide concepts in water resource management, (2) conceptual issues in system-wide modeling, and (3) computing challenges in model integration and application. Clear from these discussions was the existence of similar conceptual and technical challenges, including an ineffective dialog between practitioner groups, the need to address uncertainty, and a requirement to develop common modeling frameworks. Participants also identified a number of opportunities for positive action. Key to pursuing these opportunities will be an effective and continuing dialog.

Integration in Water Resource Management: Challenges, Concepts and Opportunities

Background

Increased societal demands on water resources threaten their sustainable use and pose difficult challenges for resource managers. Awareness of the significance of anthropogenic impacts to water resources has prompted growing public concern and governmental legislative action, especially in North America and Western Europe, since the middle of the twentieth century. During this time, threats to water resources have increased in both spatial and temporal scale (Figure 1). While early concerns for local impacts to aquatic environmental (e.g., the impact of sewage outfalls on receiving streams) heightened awareness and prompted the development of assessment tools and mitigation measures, environmental threats today exists across broad spatial and temporal scales.

Figure 1. Changes in the spatial and temporal scale of threats to water resources. Based on Straškraba (1996) and Meybeck et al. (1989).



Understanding that a system-wide approach to management is required to meet this challenge, national agencies and ministries of government are conducting research and development programs to provide the knowledge bases and decision support tools to better conduct comprehensive water resource management activities.

An International Forum

Recognition that European Union (EU) and US Army Corps of Engineers (USACE) water resource management research efforts target similar issues, and that mutual benefits would be gained through dialog and technical exchange, led to the organization and conduct of a technical forum. The intent of the forum was to discuss common issues related to the challenges of adopting a system-wide approach to water resource management. Issues related to development of decision support tools that reflect a system-wide understanding were of particular interest. The forum was held 14-16 September 2004 in North Berwick, Scotland and was attended by 25 technical representatives from the EU and USACE.

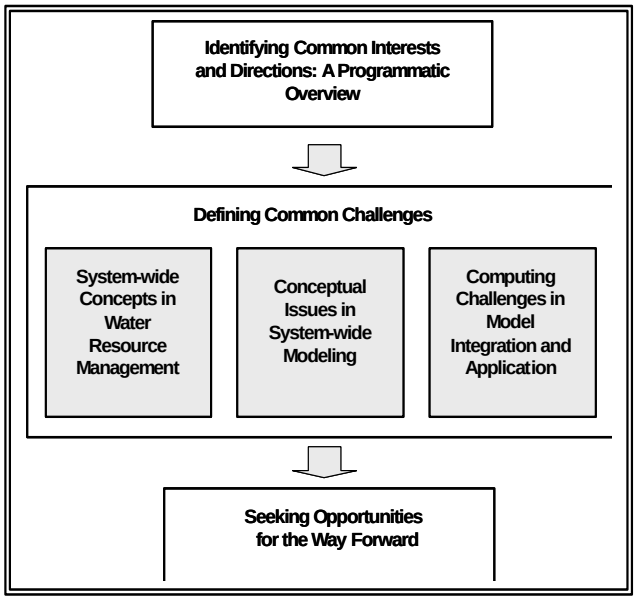


Figure 2. Forum discussion topics and organization

Overview presentations during the opening session of the forum allowed participants to more fully understand respective program objectives and planned activities. This was followed by discussion of common challenges faced within EU and USACE research and development efforts. Three linked themes guided these discussions: defining system-wide concepts for water resource management; conceptual issues in the development of system-wide models; and computational challenges posed by such a modeling approach. Plenary presentations within each theme were followed by group discussions during which participants were asked to develop, for each theme, consensus lists of (1) challenges with near-term solutions and (2) challenges requiring innovation and longer term research efforts to successfully over come. Group participants were also asked to identify opportunities for action to address each identified challenge or need. The final session focused on opportunities future collaboration.

Program Overviews

European Research for the Water Framework Directive **-** The European Parliament and Council passed the ambitious directive (2000/60/EC) in 2000 establishing a framework for Community Action in the field of water policy, known as the Water Framework Directive (WFD). The key objective of this law is to achieve 'good ecological status' for Europe's water resources, including surface water, groundwater and the

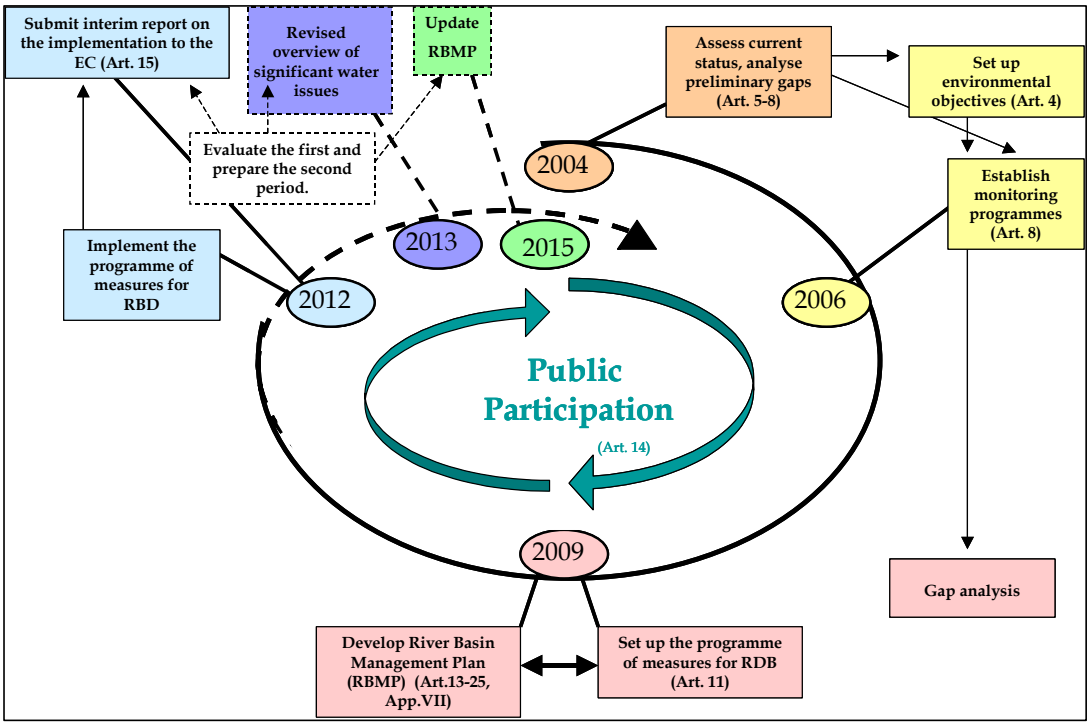


Figure 3. Visualization of the time line of the WFD, its required activities and deliverables (CIS, 2003).

coastal zone, by 2015. This will be achieved through the implementation of Integrated River Basin Management Plans (RBMP), the development of which must be completed by 2009 (Figure 3). Incorporated in each RBMP will be ameliorative measures for achieving water resource management goals. Broad support for RBMP's is to be sought through public participation and consultation with stakeholders during formulation. To insure cost effectiveness, RBMP's will follow a "polluter-pays" principle and incorporate cost recovery of measures.

The European Research Directorate has funded numerous research and development programs to support implementation of the WFD. One such program, Catchment Modeling or CatchMod, includes a number of interrelated projects focused on integrated river basin management. Each of these projects or clusters addresses specific issues on improving and facilitating modeling in large integrated systems. Other relevant research efforts target scientifically sound definition of ecological status and the relationship between morphology/physicochemical characteristics and ecological status.

U.S. Army Corps of Engineers Research and Development Initiatives - The USACE, as the principle water resource agency, is responsible for the development and management of critical water control infrastructure in the United States. While the USACE has developed knowledge bases and decision-making tools to support the management of water quantity, many of these prove to be insufficient to support its increasing focus on ecosystem sustainability and resource stewardship. The USACE's Civil Works Strategic Plan (USACE, 2004) identifies the requirement to achieve greater

Regional Water Management	**Regional Sediment Management**	**Ecosystem Assessment & Management**
• Water processes & assessments • Watershed hydrology simulation • Riverine & estuarine simulation • Coastal simulation	• River basin morphology, modeling & management • Coastal morphology, modeling & management • Sediment management methods • Sediment process studies	• Ecosystem processes & assessment • Ecological modeling • Ecosystem response forecasting
Unifying Technologies • Decision support • Geospatial applications development • Model integration • Regional measurement and monitoring • Data management • Frameworks • Knowledge management		

Figure 4. Relationship between unifying technologies, and research and development themes incorporated in the USACE's System-wide Water Resource Program.

balance between traditional demands on water resources (e.g., navigation and water supply) and environmental or ecological needs, and recognizes the need to adopt a systems approach to accomplish this.

The USACE's recently established the System-wide Water Resource Program[1] (SWWRP; Figure 4) to meet the needs for refined knowledge bases and appropriate tools to support operation, management and, if necessary, restoration of water resources. Key themes of the SWWRP, which addresses water resource management issues ranging from flood control and navigation to water quality and habitat restoration, are regional water and sediment management and ecosystem assessment and management. Central to the success of SWWRP will be the ability to integrate information from disparate sources. Toward that end, the SWWRP will include a number of unifying technologies.

[1] Personal Communication. Steven Ashby, SWWRP Program Manager, US Army Engineer Research and Development Center, Vicksburg, Mississippi.

Theme Discussions

System-wide Concepts in Water Resource Management - Water resource managers, particularly those motivated by environmental concerns, have failed to develop a complete or appropriate fundamental understanding of water resource systems, or to apply management strategies that address system-wide attributes of such systems based on this understanding. Water resource engineers, long tasked with

Challenges and Needs with Near-term Solutions	
Challenge or Need	***Opportunities for Action***
Methods and metrics for assessing risk and uncertainty	• Share information on uncertainty toolboxes and seek opportunities to collaborate in the development of new tools. • Jointly develop an international conference on risk and uncertainty, and involve resource managers and stakeholders.
More effective interactions between resource managers and technical experts	• Identify or develop examples illustrating the information sharing and modeling in resource management.
Challenges and Needs Requiring Innovation and Research	
Challenge or Need	***Opportunities for Action***
Adaptive management concepts within an integrated, system-wide framework that effectively addresses decision-making uncertainty	• Develop and conduct a US-EU twinning project. • Collaborate in conducting and evaluating long-term scenarios.
Guidelines for selecting references for identifying management goals and evaluating management outcomes.	• A twinned project offers the opportunity to explore alternative approaches to setting references.

Table 1. Summary of discussions concerning the system-wide concepts in water resource management.

predicting and influencing the movement of water through large complex hydrologic systems, have developed and routinely apply management tools (e.g., analytical solutions, numerical models) that explicitly acknowledge system-wide attributes. Managers of environmental quality, while implicitly acknowledging system-wide attributes, tend to focus on those portions of the system exhibiting ‘problem’ conditions. Effective water resource management will require a sound conceptual base that integrates quantity and quality.

Participants identified a number of similar challenges faced by both the EU and USACE (Table 1). Principal among these was insufficient or ineffective interaction between resource managers, those requiring decision-making tools, and research or technology experts, those involved in tool development. Overcoming these shortcomings will require an effective dialog between these two groups of practitioners, during which needs, expectations and technical requirements can be more fully understood.

Also addressed were uncertainty and risk, a field in which there is considerable ongoing development. Concepts related to risk are of particular interest to managers, since decision making involves balancing risk and cost. Given the importance of risk, uncertainty and ignorance, adaptive management was discussed as a potential management concept of interest[2]. For the longer term, participants agreed that there is still urgent need to improve on integration of disciplines (especially through the incorporation socio-economic considerations), approaches for ecological classification (including references) and linkage between management measures and ecological effects. It was noted that since the European WFD targets the integration across disciplines, there are now several EU-wide and national projects that offer opportunity for collaboration[3].

Conceptual Issues in System-wide Modeling - While underlying concepts form the necessary basis for developing appropriate management approaches for water resource systems, such concepts must eventually provide the framework that allows the integration of tools developed by scientists and engineers, and managers. Such practitioners develop tools reflective of their training and the challenges posed by modeling particular aspects of resource management. This discussion session addressed questions concerning the types of numerical constructs that should be integrated (i.e., what models are appropriately integrated to support system-wide concepts in water resource management, what outputs are required, and how will such outputs be applied?)

Similarities in interests and needs for future research and development were again identified during these group discussions (Table 2). Clear from these discussions was the need for the EU and USACE, both of whom are currently engaged in model

[2] Relevant EC project: NeWater (www.newater.info)
[3] Relevant EC projects: Rebecca, Star

Challenges and Needs with Near-term Solutions	
Challenge or Need	***Opportunities for Action***
Coordinate existing US and EU efforts toward model integration	• Plan and conduct a technical meeting involving HarmonIT and USACE to continue foster greater interaction. • Develop working groups to ensure continuing dialog and effective information exchange
Challenges and Needs Requiring Innovation and Research	
Challenge or Need	***Opportunities for Action***
Conceptualizing management approaches and selecting appropriate model techniques.	• Develop guidance that identifies model types appropriate for generalized sets of management issues • Develop "demonstration models" as a means to demonstrate to decision-makers the usefulness of numeric tools and a system-wide approach
Concepts (what and why) and approaches (how and when) for information exchange between physical/chemical models and ecological models.	• Develop a compendium of language, unit and discipline-specific obstacles to effective model integration
Decision support tools that effectively integrate science, engineering, economics and social dynamics.	• Establish a joint working group to better define the need for and characteristics of models and informatics tools that address social and economic interactions with water resources
Integration of climate change, and water and environmental resources analyses.	• Develop appropriate linkages between climate change models and water resource management models; alternatively, incorporate climate change as an uncertainty estimate

Table 2. Summary of discussions of conceptual issues in system-wide modeling.

development research, to coordinate activities and exchange information beginning immediately. However, many of the more difficult challenges will require longer-term efforts. These include how best to exchange information between models operating on different spatial or temporal scales and employing different modeling constructs. It was agreed that effective resource management tools must incorporate interactions with social and economic influences, and that the effects of climate change must be addressed, perhaps as a source of uncertainty.

Computing Challenges in Model Integration and Application - Identifying models and modeling approaches appropriate for integration, and successfully performing such integration offer unique challenges. For example, engineers and life scientists often describe processes and system state using different terms and measures. While the

Challenges and Needs with Near-term Solutions	
Challenge or Need	***Opportunities for Action***
Standard model connectivity data and objects, and related transfer procedures	• Establish a joint committee to set interface standards. Circulate UASCE data standards and web services designs with EU researchers. (Note: there are no near-term EU plans to establish data standards.)
A common IT framework for model connectivity	• Conduct a joint workshop to identify issues for which such a common framework is appropriate and map collaboration to meet this need.
Consolidated model libraries	• Compile and share existing libraries and supporting documentation. (Note: Issues of licensing and commercial interest will have to be addressed as required.)
Challenges and Needs Requiring Innovation and Research	
Challenge or Need	***Opportunities for Action***
Library objects based on modularized models	• Establish a dialog to assess the merits, including cost-benefit considerations, of modularized models and determine specific needs or applications.
High performance computing	• Appoint EU and USACE technical liaisons to ensure a continuing sharing of developmental progress.

Table 3. Summary of discussions concerning the computational challenges of system-wide water resource modeling.

engineer or chemist may develop mechanistic models that account for changes in state over short time intervals using measures of mass or concentration, biologists might recognize individuals or developmental stages on greater spatial or temporal scales and may lack a sufficient ecological understanding to develop mechanistic models. Despite this disparity, the linking of such models or the exchange of information between models will often be desirable. How can this be accomplished with fidelity, reduced error rates and with appropriate treatment of spatial and temporal scales? Can differences between modeling approaches be overcome to allow the models to be fully integrated/coupled? This discussion addressed the range of computer science challenges posed by model integration.

Discussion of these technological issues provided insight to complementarities in EU and USACE research challenges, as well as disparities in approach taken by each (Table 3). Europe has made strong advances in generic linkage, while the USACE has focused efforts on data-objects (common databases) and parallel computing.

A Way Forward

Clear from discussions during this forum is the need for a effective long-term interaction between EU and USACE researchers. Both the EU and USACE are and will continue to pursue aggressive research and development programs motivated their water resource management challenges and the needs of their specific user community. Discussions of each of the themes above led to the identification of a number of opportunities for action (see Tables 1-3). Successfully pursuing these opportunities will require and concerted effort by both the EU and USACE research and development communities to remain engaged and to identify mechanisms that support collaboration. Initial efforts requiring limited resources include[4]:

- Establishing points of contact through whom efforts can be coordinated,
- Exchange information on HarmonIT and provide full USACE access to the Harmoni-CA web portal,
- Review the usefulness of Harmoni-CA toolbox for USACE needs,
- Review the usefulness of USACE toolboxes for EU work and,
- Bring together USACE experts on adaptive management with the EU's NeWater project

References

CIS (Common Strategy on the Implementation of the WFD) (2003). *Best Practices in River Basin Planning*. Work Package 2: Guidance on the Planning Process, 88pp.

European Commission. 2000. Directive of the European Parliament and of the Council 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy, Official Journal 2000 L 327/1, European Commission, Brussels, Belgium.

Meybeck, M., D. V. Chapman, and R. Helmer (eds). 1990. Global Freshwater Quality - A First Assessment. World Health Organization and United Nations Environment Programme, Blackwell Reference, Oxford. 306p.

Straškraba, M. 1996. Lake and reservoir management. Verh. Internat. Verein. Limnol. 26:193-209.

USACE. 2004. Civil Works Strategic Plan. Office of the Chief, US Army Corps of Engineers, Washington, DC.

[4] Representatives from HarmonIT met on 23-24 March 2005 with USACE representatives at the Engineer Research and Development Center in Vicksburg, Mississippi to exchange information on OpenMI and USACE efforts in model integration

Appendix - List of Participants

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